(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 172 811 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.01.2002 Bulletin 2002/03

(51) Int Cl.7: G11B 7/24

(21) Application number: 01306008.2

(22) Date of filing: 12.07.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 13.07.2000 JP 2000212338
26.04.2001 JP 2001128904

(71) Applicant: Matsushita Electric Industrial Co., Ltd.
Kadoma-shi, Osaka-fu, 571-8501 (JP)

(72) Inventors:
- Kojima, Rie
Kadoma-shi, Osaka 571-0030 (JP)
- Nishihara, Takashi
Osaka-shi, Osaka 532-0022 (JP)
- Yamada, Noboru
Hirakata-shi, Osaka 573-1104 (JP)

(74) Representative: Jeffrey, Philip Michael
Frank B. Dehn & Co. 179 Queen Victoria Street
London EC4V 4EL (GB)

(54) **Information recording medium, method for producing the same, and recording/reproducing method using the same**

(57) An information recording medium 10 of the present invention includes a first substrate 11, a second substrate 12 disposed so as to be opposed to the first substrate 11, a first information layer 13 disposed between the first substrate 11 and the second substrate 12, a second information layer 14 disposed between the first information layer 13 and the second substrate 12, and an intermediate layer 15 disposed between the first information layer 13 and the second information layer 14. The first information layer 13 includes a first recording layer 18 that is transformed in phase reversibly between a crystal phase and an amorphous phase with a laser beam 35, and the second information layer 14 includes a second recording layer 27 that is transformed in phase reversibly between a crystal phase and an amorphous phase. The first recording layer 18 contains, Ge, Sn, Sb, and Te, and has a thickness of 9 nm or less.

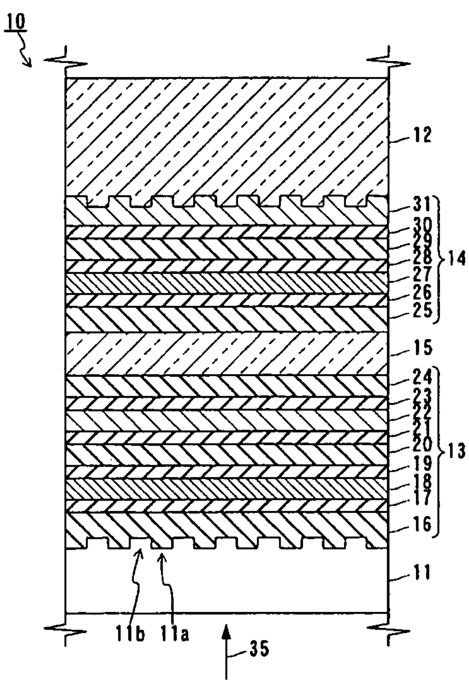

Fig. 1

EP 1 172 811 A2

Description

[0001] The present invention relates to an information recording medium for optically recording, erasing, rewriting, and reproducing information, a method for producing the same, and a method for recording/reproducing information with respect to the same.

[0002] In a phase-change information recording medium, information is recorded, erased and rewritten using a recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase. When this recording layer is irradiated with a high power laser beam and then is cooled rapidly, a portion thus irradiated is changed to be in an amorphous phase. Similarly, when an amorphous portion of the recording layer is irradiated with a low power laser beam and then is cooled slowly, the portion thus irradiated is changed to be in a crystal phase. Therefore, in the phase-change information recording medium, the recording layer is irradiated with laser beams having powers modulated between a high power level and a low power level, whereby the information layer can be changed freely to be in an amorphous phase or a crystal phase. In the phase-change information recording medium, information is recorded using the difference in reflectivity between an amorphous phase and a crystal phase.

[0003] In recent years, in order to enhance the recording density of an information recording medium, various techniques have been studied. For example, there are techniques of recording a smaller recording mark using a violet laser beam and of recording a smaller recording mark by making a substrate thinner on a light incident side while using a lens with a large numerical aperture. A technique of recording/reproducing information with respect to two recording layers using a laser beam incident from one side also has been studied (see JP 12 (2000)-36130 A).

[0004] In order to decrease the size of a recording mark, it is necessary to shorten an irradiation time of a laser beam used for changing a phase of a recording layer. This requires that the crystallization speed of the recording layer should be high. Furthermore, in order to record/reproduce information with respect to two recording layers, it is required to use a thin recording layer on a light incident side so that sufficient light reaches a recording layer on the back side. However, when the recording layer is thinned, the number of atoms contained in the recording layer is decreased, and the movement of atoms involved in a phase change also is suppressed, which lowers the crystallization speed. Therefore, there is a demand for a material capable of forming a recording layer on which information can be recorded with reliability irrespective of its thinness.

[0005] Conventionally, as a material for a recording layer, Ge-Sb-Te system materials have been used. According to an experiment by the inventors of the present invention, it is found that, among them, a pseudo binary composition $GeTe\text{-}Sb_2Te_3$ has the highest crystallization speed, and $Ge_2Sb_2Te_5$ ($(GeTe) : (Sb_2Te_3) = 2 : 1$) has excellent characteristics. Furthermore, Uno et al. report a recording/reproducing experiment using a Ge-Sb-Te recording layer with a thickness of 6 nm (M. Uno, K. Nagata and N. Yamada, "Thinning Limitation of Ge-Sb-Te Recording Film for High Transmittance Media", Proc. of PCO'99. 83-88). In this experiment, information was erased at a linear velocity of 9 m/s using a laser with a wavelength of 660 nm, and a satisfactory erasure ratio (30 dB) was obtained.

[0006] However, when the inventors conducted an experiment on a Ge-Sb-Te system material, using a violet laser with a wavelength of 405 nm, this material was found to be insufficient for use on a light incident side. Therefore, in a conventional recording layer, it was difficult to realize an information recording medium having a two-layered structure, with respect to which information is recorded/reproduced using a violet laser.

[0007] JP 2(1990)-147289 A reports that an information recording medium is obtained that has excellent repeated-recording/erasing characteristics and less change in an erasure ratio with time by adding Sb to Te-Ge-Sn of a recording layer so as to limit the content of each element. However, this is an experimental result in the case where an information recording medium includes only one recording layer, and the recording layer is thick (i.e., 30 to 100 nm). This publication does not show the effects of addition of Sn in the case where the recording layer is thinned.

[0008] Therefore, with the foregoing in mind, it is an object of the present invention to provide a high-density recordable information recording medium having two recording layers, a method for producing the same, and a method for recording/reproducing information with respect to the same.

[0009] In order to achieve the above-mentioned object, an information recording medium of the present invention includes: a first substrate; a second substrate disposed so as to be opposed to the first substrate; a first information layer disposed between the first substrate and the second substrate; a second information layer disposed between the first information layer and the second substrate; and an intermediate layer disposed between the first information layer and the second information layer, wherein the first information layer includes a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase with a laser beam radiated from the first substrate side, the second information layer includes a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase with the laser beam, and the first recording layer contains Ge, Sn, Sb, and Te, and has a thickness of 9 nm or less.

[0010] In the above-mentioned information recording medium, the first recording layer may be made of a material represented by a composition formula: $(Ge\text{-}Sn)_ASb_BTe_{3+A}$, where $2 \leq A \leq 22$ and $2 \leq B \leq 4$. This composition formula represents that Ge and Sn are contained in the material by $100 * A/(2A + B + 3)$ atomic % in total. According to this

constitution, even when the first recording layer is made thin, satisfactory recording/erasing characteristics are obtained with a violet laser. By setting $2 \leq A$, an amplitude of a signal can be increased. Furthermore, by setting $A \leq 22$, a decrease in crystallization speed can be prevented. By setting $2 \leq B$, Te, which has a low melting point, can be prevented from being precipitated when a phase change between a crystal phase and an amorphous phase is effected. In the case of $2 < B$, an excess amount of Sb is added to the material represented by $(Ge - Sn)_A Sb_2 Te_{3+A}$. This excess amount of Sb functions to increase a crystallization temperature to enhance thermal stability of a recording mark, and suppressing the movement of a substance during repeated-recording.

[0011] In the above-mentioned information recording medium, a content of Sn in the first recording layer may be 25 atomic % or less. The content of Sn preferably is 0.1 atomic % or more. According to this constitution, even when the first recording layer is made thin, a satisfactory erasure ratio is obtained with a violet laser. Furthermore, by adjusting the content of Sn in the first recording layer and B, the crystallization speed and the crystallization temperature of the first recording layer can be controlled.

[0012] In the above-mentioned information recording medium, a transmittance Tc (%) of the first information layer in a case where the first recording layer is in a crystal phase, and a transmittance Ta (%) of the first information layer in a case where the first recording layer is in an amorphous phase may satisfy $40 \leq (Tc + Ta)/2$ with respect to a laser beam having a wavelength in a range of 390 nm to 430 nm. According to this constitution, satisfactory recording/erasing characteristics also are obtained in the second information layer.

[0013] In the above-mentioned information recording medium, the transmittance Tc (%) and the transmittance Ta (%) may satisfy $0 \leq |Tc - Ta|/Tc \leq 0.15$ (more preferably, $0 \leq |Tc - Ta|/Tc \leq 0.05$) with respect to a laser beam having a wavelength in a range of 390 nm to 430 nm. According to this constitution, a change in recording sensitivity of the second information layer can be decreased irrespective of a recorded state of the first information layer

[0014] In the above-mentioned information recording medium, the first information layer further may include first and second dielectric layers and a first reflective layer, and the first reflective layer, the second dielectric layer, the first recording layer and the first dielectric layer may be disposed in this order from the intermediate layer side to the first substrate side. According to this constitution, by varying a material and a thickness of the dielectric layers and the reflective layers, the light absorptivity of the first recording layer, and the transmittance and the reflectivity of the first information layer can be controlled.

[0015] In the above-mentioned information recording medium, the first information layer further may include a third dielectric layer disposed between the first reflective layer and the intermediate layer. According to this constitution, by varying a material and a thickness of the third dielectric layer, the transmittance of the first information layer can be increased.

[0016] In the above-mentioned information recording medium, a refractive index of the third dielectric layer may be 2.3 or more with respect to light having a wavelength in a range of 390 nm to 430 nm.

[0017] In the above-mentioned information recording medium, grooves for tracking control may be formed on the intermediate layer.

[0018] In the above-mentioned information recording medium, the first information layer further may include an interface layer disposed at at least one interface selected from the group consisting of an interface between the first dielectric layer and the first recording layer, an interface between the first recording layer and the second dielectric layer, an interface between the second dielectric layer and the first reflective layer, and an interface between the first reflective layer and the third dielectric layer. According to this constitution, the movement of a substance between layers can be suppressed, so that an information recording medium with high reliability is obtained.

[0019] In the above-mentioned information recording medium, a thickness of the first reflective layer may be in a range of 5 nm to 15 nm. According to this constitution, the transmittance Tc (%) and Ta (%) of the first information layer can be enhanced, and the first recording layer easily can be changed to be in an amorphous phase by rapidly diffusing heat generated therein. When the first reflective layer is too thin, its heat diffusion function is insufficient, and when it is too thick, the transmittance of the first information layer becomes insufficient. Therefore, the thickness of the first reflective layer preferably is set in a range of 5 nm to 15 nm.

[0020] In the above-mentioned information recording medium, a thickness of the first substrate may be in a range of 10 μm to 700 μm. According to this constitution, by varying a numerical aperture NA of an objective lens, the length of a recording mark and the interval between recording marks can be optimized in accordance with the shape of grooves of the first substrate and recording/erasing/reproducing conditions.

[0021] In the above-mentioned information recording medium, grooves for tracking control may be formed on the first substrate.

[0022] In the above-mentioned information recording medium, a thickness of the second substrate may be in a range of 500 μm to 1300 μm. According to this constitution, by varying a numerical aperture NA of an objective lens, the length of a recording mark and the interval between recording marks can be optimized in accordance with the shape of grooves of the first substrate and recording/erasing/reproducing conditions. The thickness of the second substrate is selected so that the thickness of the information recording medium becomes about 1200 μm. In the case where the

thickness of the first substrate is about 100 μm, the thickness of the second substrate is set to be about 1100 μm. Furthermore, in the case where the thickness of the first substrate is about 600 μm, the thickness of the second substrate is set to be about 600 μm.

[0023] In the above-mentioned information recording medium, grooves for tracking control may be formed on the second substrate.

[0024] In the above-mentioned information recording medium, the second information layer further may include fourth and fifth dielectric layers and a second reflective layer, and the second reflective layer, the fifth dielectric layer, the second recording layer and the fourth dielectric layer may be disposed in this order from the second substrate side to the intermediate layer side. According to this constitution, by varying a material and a thickness of the dielectric layers and the reflective layers, the light absorptivity of the second recording layer and the reflectivity of the second information layer can be controlled.

[0025] In the above-mentioned information recording medium, the second information layer further may include an interface layer disposed at at least one interface selected from the group consisting of an interface between the fourth dielectric layer and the second recording layer, an interface between the second recording layer and the fifth dielectric layer, and an interface between the fifth dielectric layer and the second reflective layer.

[0026] Furthermore, a method for producing an information recording medium of the present invention is a method for producing an information recording medium including first and second substrates, first and second information layers, and an intermediate layer, the method including the processes of: (a) forming the second information layer on the second substrate; (b) forming the intermediate layer on the second information layer; (c) forming the first information layer on the intermediate layer; and (d) attaching the first substrate on the first information layer, wherein the first information layer includes a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase with a laser beam radiated from the first substrate side, the second information layer includes a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase with the laser beam, and the process (c) includes the process of forming the first recording layer to a thickness of 9 nm or less, using a base material containing Ge, Sn, Sb, and Te. According to this production method, the information recording medium of the present invention can be produced easily. Furthermore, according to this production method, since the first substrate is stacked after the second information layer and the first information layer are formed, an information recording medium provided with a first thin substrate can be produced easily.

[0027] According to the above-mentioned production method, in the process (c), the first recording layer may be formed by sputtering using sputtering gas containing argon gas or krypton gas. According to this constitution, an information recording medium with excellent repeated-recording characteristics can be formed easily.

[0028] According to the above-mentioned production method, the sputtering gas further may contain at least one gas selected from the group consisting of oxygen and nitrogen.

[0029] According to the above-mentioned production method, the first recording layer may be formed at a film-formation speed in a range of 0.1 nm/second to 10 nm/second. According to this constitution, the variations in thickness of the first recording layer can be decreased, and the first recording layer can be produced with good productivity in a short period of time.

[0030] According to the above-mentioned production method, in the process (b), grooves for tracking control may be formed on a surface of the intermediate layer.

[0031] Furthermore, according to the above-mentioned production method, the first information layer further may include a first reflective layer disposed on the intermediate layer side from the first recording layer, and the process (c) may include the process of forming the first reflective layer in a range of 5 nm to 15 nm.

[0032] Furthermore, a recording/reproducing method of the present invention is a method for recording/reproducing an information signal by irradiating an information recording medium with a laser beam, wherein the information recording medium is the above-mentioned information recording medium of the present invention, the laser beam is incident from the first information layer side of the information recording medium, in the second information layer of the information recording medium, information is recorded/reproduced with the laser beam transmitted through the first information layer, and a wavelength of the laser beam is in a range of 390 nm to 430 nm. According to this recording/reproducing method, high-density recording can be conducted with high reliability.

[0033] In the above-mentioned recording/reproducing method, a linear velocity of the information recording medium in recording/reproducing information may be in a range of 1 m/second to 50 m/second. According to this constitution, the length of a recording mark and the interval between recording marks can be optimized in accordance with the structure of an information recording medium and recording/reproducing conditions, and a high transfer rate can be realized.

[0034] In the above-mentioned recording/reproducing method, the laser beam may be a laser beam condensed by an objective lens with a numerical aperture NA in a range of 0.4 to 1.1. According to this constitution, the length of a recording mark and the interval between recording marks can be optimized in accordance with the thickness of the first substrate or the second substrate, the shape of grooves, and recording/erasing/reproducing conditions, and a high

transfer rate can be realized.

[0035] These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

[0036] Figure 1 is a partial cross-sectional view showing an exemplary information recording medium of the present invention.

[0037] Figure 2 is a diagram showing a composition range of a first recording layer in the information recording medium of the present invention.

[0038] Figure 3 is a partial cross-sectional view showing another exemplary information recording medium of the present invention.

[0039] Figure 4 is a view schematically showing an exemplary structure of a recording/reproducing apparatus used for a recording/reproducing method of the present invention.

[0040] Figure 5 is a partial cross-sectional view showing a structure of a sample used for evaluating the information recording medium of the present invention.

[0041] Figure 6 is a diagram schematically showing a structure of an evaluation apparatus used for evaluating the information recording medium of the present invention.

[0042] Hereinafter, the present invention will be described by way of illustrative embodiments with reference to the drawings. The following embodiments are shown merely for illustrative purpose, and the present invention is not limited thereto.

Embodiment 1

[0043] In Embodiment 1, an exemplary information recording medium of the present invention will be described. Figure 1 shows a partial cross-sectional view of an information recording medium 10 of Embodiment 1.

[0044] Referring to Figure 1, the information recording medium 10 includes a first substrate 11 (hatching is omitted), a second substrate 12 disposed so as to be opposed to the first substrate 11, a first information layer 13 disposed between the first substrate 11 and the second substrate 12, a second information layer 14 disposed between the first information layer 13 and the second substrate 12, and an intermediate layer 15 disposed between the first information layer 13 and the second information layer 14. Information is recorded/reproduced with respect to the information recording medium 10 with a laser beam 35 incident from the first substrate 11 side.

[0045] The first substrate 11 and the second substrate 12 are respectively disk-shaped transparent substrates. As shown in Figure 1, grooves for tracking control may be formed, if required, on the inner surfaces (on the intermediate layer 15 side) of the first substrate 11 and the second substrate 12. The outer surfaces of the first substrate 11 and the second substrate 12 generally are smooth. In the case where grooves are formed on the substrate, information may be recorded on grooves 11a (groove surface closer to the incident side of the laser beam 35) or on portions (groove surface far away from the incident side of the laser beam 35, hereinafter, referred to as "lands 11b") between the grooves 11a. Information also may be recorded on both the grooves 11a and the lands 11b.

[0046] The first substrate 11 and the second substrate 12 can be made of glass or resin such as polycarbonate, amorphous polyolefin, and polymethylmethacrylate (PMMA). Among them, polycarbonate resin is preferable because this resin makes it easy to form grooves and has good productivity. It is preferable that the first substrate 11 has a small birefringence with light of a wavelength in a range of 390 nm to 430 nm. The thickness of the first substrate 11 preferably is in a range of 10 μm to 700 μm (more preferably, 50 μm to 150 μm). As the first substrate 11 becomes thinner, the numerical aperture of an objective lens can be increased, and the laser beam 35 can be focused. For example, in the case where the thickness of the first substrate 11 is 100 μm, information can be recorded/erased satisfactorily by using an objective lens with a numerical value of 0.85. Furthermore, in the case where the thickness of the first substrate 11 is 600 μm, information can be recorded/erased satisfactorily by using an objective lens with a numerical value of 0.6. The thickness of the second substrate 12 preferably is in a range of 500 μm to 1300 μm (more preferably, 900 μm to 1300 μm).

[0047] The first information layer 13 includes a third dielectric layer 24, a fourth interface layer 23, a first reflective layer 22, a third interface layer 21, a second dielectric layer 20, a second interface layer 19, a first recording layer 18, a first interface layer 17, and a first dielectric layer 16 that are disposed successively from the intermediate layer 15 side to the first substrate 11 side. Furthermore, the second information layer 14 includes a second reflective layer 31, a seventh interface layer 30, a fifth dielectric layer 29, a sixth interface layer 28, a second recording layer 27, a fifth interface layer 26 and a fourth dielectric layer 25 that are disposed successively from the second substrate 12 side to the intermediate layer 15 side.

[0048] It is preferable that a transmittance Tc (%) of the first information layer 13 in the case where the first recording layer 18 is in a crystal phase and a transmittance Ta (%) of the first information layer 13 in the case where the first recording layer 18 is in an amorphous phase satisfy $40 \leq (Tc + Ta)/2$ with respect to a laser beam having a wavelength in a range of 390 nm to 430 nm. It also is preferable that Tc and Ta satisfy $0 \leq |Tc - Ta|/Tc \leq 0.15$ (more preferably, 0

≤ |Tc - Ta| /Tc ≤ 0.05).

[0049] The first, second and third dielectric layers 16, 20 and 24 have a function of protecting the first recording layer 18 from the environment. Furthermore, by selecting a thickness and a material for each layer, the light absorptivity (%) of the first recording layer 18, and the reflectivity and transmittance of the first information layer 13 can be controlled with the use of light interference.

[0050] Each thickness of the above-mentioned dielectric layers can be determined, for example, by using calculation based on a matrix method (see "Wave Optics" by Hiro Kubota, Iwanami-shoten, 1971, Ch. 3). More specifically, each thickness can be determined strictly so as to satisfy the conditions that |Rc - Ra| or Rc/Ra becomes larger and Tc and Ta become larger. Herein, Rc and Tc represent a reflectivity (%) and a transmittance (%) of the first information layer 13 in the case where the first recording layer 18 is in a crystal phase. Ra and Ta represent a reflectivity (%) and a transmittance (%) of the first information layer 13 in the case where the first recording layer 18 is in an amorphous phase.

[0051] Each complex refractive index of the dielectric layers in the vicinity of a wavelength of 400 nm is an important factor for determining the light absorptivity of the first recording layer 18, and the reflectivity and transmittance of the first information layer 13. A complex refractive index is represented by (n - k·i) (where n is a refractive index, and k is an extinction coefficient). In order to keep large Tc and Ta, it is desirable that transparency of the dielectric layers is high. More specifically, it is desirable that an extinction coefficient k is 0.1 or less.

[0052] Regarding the refractive index of the dielectric layers, the inventors investigated the influence of a refractive index n1 of the first dielectric layer 16, a refractive index n2 of the second dielectric layer 20, and a refractive index n3 of the third dielectric layer 24 on the reflectivity and the transmittance of the first information layer 13 by simulation using the matrix method. This simulation was conducted assuming that the thickness of the first recording layer 18 is 6 nm, and that of the first reflective layer 22 is 10 nm. Consequently, the following results were obtained. In the case where the refractive indexes n1, n2, and n3 satisfy the relationships: 1.7 ≤ n1 ≤ 2.5, 1.7 ≤ n2 ≤ 2.8, and 2.0 ≤ n3, the thickness of the dielectric layers that allows I Rc - Ra I or Rc/Ra to be large and satisfies 40 ≤ (Tc + Ta)/2 can be determined. Furthermore, in the case where n1, n2, and n3 satisfy the relationships: 2.1 ≤ n1 ≤ 2.4, 2.0 ≤ n2 ≤ 2.8, and 2.2 ≤ n3, Ra can be set to be small, so that the thickness that allows Rc/Ra to be large and satisfies 50 ≤ (Tc + Ta)/2 can be determined.

[0053] In this manner, the first, second and third dielectric layers 16, 20 and 24 have a function of increasing a transmittance (Tc and Ta) of the first information layer 13. Among them, the third dielectric layer 24 particularly is important, and it is preferable that the third dielectric layer 24 is made of a material with a large refractive index (e.g., a material with a refractive index of 2.3 or more). It also was confirmed by calculation that in the presence of the third dielectric layer 24, the transmittance of the first information layer 13 is increased by 5% to 10% in an absolute value, compared with the case where there is no third dielectric layer 24.

[0054] Next, preferable thermal characteristics of the dielectric layers will be described. In order to form a satisfactory recording mark on the first recording layer 18, it is important to allow heat generated in the first recording layer 18 due to light absorption to radiate rapidly in a thickness direction and to cool the first recording layer 18 rapidly. Because of this, it is preferable that the first dielectric layer 16 and the second dielectric layer 20 are made of a material with a relatively small heat conductivity. When a material with a large heat conductivity is used, heat is likely to radiate in an in-plane direction, which relatively decreases a rapid cooling speed of the first recording layer 18. In order to increase a rapid cooling speed of the first recording layer 18, it is preferable that the third dielectric layer 24 formed on the first reflective layer 22 is made of a material with a relatively large heat conductivity.

[0055] The first, second, and third dielectric layers 16, 20, and 24 are made of a material satisfying the above-mentioned optical and thermal conditions. These dielectric layers can be made of an oxide, a nitride, an oxide nitride, a sulfide, a carbide, or a mixture thereof. As the oxide, for example, In_2O_3, Nb_2O_5, SnO, TiO_2, MgO, ZnO, ZrO_2, TeO_2, Al_2O_3, SiO_2 or Ta_2O_5 can be used. As the nitride, for example, Si-N, Al-N, Ti-N, Ta-N, Zr-N or Ge-N can be used. As the oxide nitride, for example, Al-O-N or Si-O-N can be used. As the sulfide, for example, ZnS can be used. As the carbide, for example, SiC can be used. As the mixture, for example, ZnS-SiO_2 can be used.

[0056] Among them, ZnS-SiO_2 is suitable for the first dielectric layer 16 and the second dielectric layer 20. ZnS-SiO_2 is a transparent amorphous material with a refractive index of about 2.3, which has a high film formation speed, and excellent mechanical properties and moisture resistance. A material with a refractive index of 2.3 or more such as TeO_2, ZnO, Ta_2O_5, ZrO_2 or TiO_2 is suitable for the third dielectric layer 24.

[0057] The first interface layer 17 and the second interface layer 19 have a function of preventing a substance from moving between the first dielectric layer 16 and the first recording layer 18 and between the first recording layer 18 and the second dielectric layer 20. Furthermore, the third interface layer 21 and the fourth interface layer 23 prevent a substance from moving between the second dielectric layer 20 and the first reflective layer 22 and between the first reflective layer 22 and the third dielectric layer 24. For example, in the case of using a dielectric layer made of ZnS-SiO_2, sulfur in the dielectric layer is prevented from diffusing to the first recording layer 18 and the first reflective layer 22. These interface layers may be omitted. However, in the case of using a dielectric layer made of a sulfide, it is preferable to form interface layers. In order to increase a transmittance of the first information layer 13, it is preferable